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AGE-SIZE STRUCTURE OF RED GROUPER, (*Epinephelus morio*), FROM THE EASTERN GULF OF MEXICO

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ABSTRACT: Sagittal otoliths from 534 red grouper, *Epinephelus morio*, were collected from recreational and commercial fisheries of the eastern Gulf of Mexico in 1979-1981 (236 fish) and 1991-1992 (298 fish). Age estimations for the two collections were made in 1991-1992 from the surface and transverse sections of these otoliths. Also, estimates of back-calculated size at age (using the final annulus present at time of capture following Lea's (1910) method were made for these collections. Red grouper were larger in size at capture at age and back-calculated size at age in 1991-1992 than in 1979-1981. The respective von Bertalanffy growth paramaters were:

$$1979\text{-}81\ L_\infty = 78.9,\ K = 0.1778,\ t_o = 0.8259$$
$$1991\text{-}92\ L_\infty = 92.6,\ K = 0.1588,\ t_o = 0.9323$$

where L_∞ is mean maximum attainable total length in centimeters, K is growth coefficient, and t_o is hypothetical age in years at which fish would have zero length.

The red grouper, *Epinephelus morio*, is a demersal marine fish that is abundant in the eastern Gulf of Mexico. It inhabits the Florida shelf from nearshore to depths of at least 110 m. Edges of reefs and areas of low-relief limestone bottoms are favored habitats for this serranid (Bullock and Smith, 1991). This species is a protogynous hermaphrodite (Moe, 1969).

Separation of red grouper from an amalgamation of groupers in fishery landings statistics did not occur until 1986. The 1989 landings indicate that about 67% (3.3 million kg) of the commercial grouper landings and about 29% (1.9 million kg) of the recreational grouper landings consisted of this species (Goodyear and Schirripa, 1991).

Age composition of the landings is vital to the determination of the status of the stock and to provide management advice. We present here a comparison of the age and size composition of red grouper in the fishery in the eastern Gulf of Mexico from two time periods, 1979-81 and 1991-92. Previous information on age-size structure of this species was reported for the 1960s for the Florida west coast (Moe, 1969) and for 1972-88 for the U.S. Atlantic coast (Stiles and Burton, ms). We follow the same pattern of study as that of Johnson et al. (1993) for the gag, *Mycteroperca microlepis*.

MATERIALS AND METHODS

The red grouper fisheries (recreational and commercial) of the eastern Gulf of Mexico (Louisiana to Key West, Florida), were sampled from April 1979 to August 1981 (period henceforth referred to as T1) and February 1991 to October 1992 (T2). These fisheries are mainly hook and line with some long line fishing.

Body length was measured at the time of sampling in mm fork length for 254 fish in T1 and in either mm or cm total length, or mm fork length, for 321 fish in T2. Collection, treatment, and processing of otoliths, as well as analysis of the data

were the same as those of Johnson et al. (1993).

RESULTS

Surface and section counts of annuli coincided for 93.7% of the T1 red grouper and 92.1% of the T2 red grouper. The overall agreement between surface and section counts was 92.9% and the agreement between two readers was 96.4%. After elimination of samples that were in disagreement, data from 236 T1 fish and 298 T2 fish were used for analysis. Fork length (FL) measurements in mm were converted to total length (TL) in mm using the equation TL = 4.7708 + 1.0307 FL which was developed from the 1992 red grouper collection (r^2 = 0.99). TLs were then reconverted from mm to cm. The analyses of the age-length data obtained from the T1 fish and the T2 fish indicated several differences between the collections. These differences were:

1. Mean fish size at capture of 66.1 cm TL (n = 298) in T2 was significantly larger than mean fish size at capture of 57.5 cm TL (n = 236) in T1 (P = 0.0001). Size at capture distributions of the two collections were: mean for T1 fish = 57.5 ± 12.5 (range 30.9-85.0) cm TL and mean for the T2 fish = 66.1 ± 10.0 (range 37.5-90.0) cm TL. The size distributions indicate that T1 had more small fish (≤60 cm TL) than T2 (62.7% and 37.9%, respectively). The size distributions of T1 and T2 (Fig. 1) were significantly different (Kolmogorov-Smirnov two-sample test, D = 0.265, $D_{\alpha=0.001}$ = 0.170, P<0.001).
2. The T2 red grouper were significantly larger by age than T1 red grouper at capture (Table 1, ages 4-11) and at age (Table 2, ages 5-9).
3. The age frequency distributions of T1 and T2 red grouper were different (Kolmogorov-Smirnov two-sample test, D = 0.130, $D_{\alpha=0.01}$ = 0.142, 0.05>P>0.01). Five-year-old fish comprised 25.8% of both collections and five-year-old and younger fish were 49.2% and 36.2% of T1 and T2 collections, respectively. The age distributions of the two collections were: mean for T1 fish = 6.4 ± 3.0 (range 2-18) yrs; and mean for T2 fish = 6.4 ± 1.9 (range 3-16) yrs. The values of age distribution by length intervals are presented in Table 3, which indicates that fish of the 1991-92 period are younger in the length intervals greater than 60 cm TL than fish of the 1979-81 period.
4. Relations between theoretical growth in length and age of the collections as described by von Bertalanffy equations were:

   T1 - back-calculated length at age (Table 2)

   $$L_t = 78.9\ (1\text{-}e^{-0.1778\ (t+0.8259)})$$

   95% C.I.: $L\infty$ ± 3.8, K ± 0.3074, t_o ± 0.5189

   T2 - back-calculated length at age

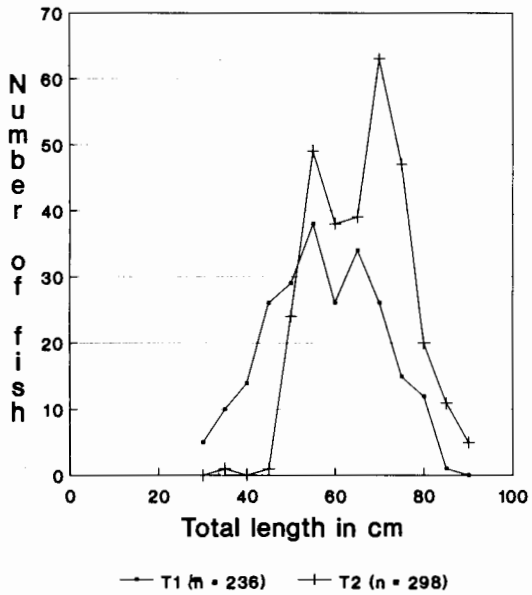

Figure 1. Size distributions of red grouper from the eastern Gulf of Mexico. Distribution plotted by 5 cm total length intervals. T1 is Apr. 1979 to Aug. 1981 and T2 is Feb. 1991 to Oct. 1992.

Table 1. Mean size at capture by age of red grouper, *Epinephelus morio*, from the eastern Gulf of Mexico in 1979-81 (T1) and 1991-92 (T2).

	T1				T2				T1/T2
		Length at capture[1]				Length at capture[1]			
Age (yrs)	No. of fish	$\bar{X}$	SD	Range	No. of fish	$\bar{X}$	SD	Range	Difference[2]
2	9	35.8	7.1	30.9–52.8	0	---	---	---	---
3	24	44.4	8.9	32.4–61.8	5	51.0	11.3	37.5–68.7	0.1608
4	22	51.5	8.9	36.0–64.9	26	55.7	4.9	45.0–64.0	0.0443*
5	61	53.5	7.6	41.2–69.8	77	61.2	7.7	51.1–90.0	0.0001*
6	33	57.6	9.4	40.2–78.3	71	63.5	7.9	48.0–78.0	0.0011*
7	24	61.9	8.4	42.7–72.1	52	70.9	6.5	51.0–86.0	0.0001*
8	19	63.9	9.5	40.2–78.3	30	74.2	7.0	58.0–87.0	0.0001*
9	6	64.3	10.0	54.1–75.8	13	75.8	5.6	61.0–82.2	0.0048*
10	9	75.9	4.9	68.0–81.9	16	77.4	8.2	53.2–89.0	0.6094
11	8	72.9	6.0	65.4–82.4	3	83.0	6.6	77.0–83.0	0.0369*
12	10	74.3	3.8	69.5–79.8	2	77.2	5.1	72.0–83.0	0.2424*
13	6	68.7	6.8	60.3–78.2	0	---	---	---	---
14	1	85.0	---	---	0	---	---	---	---
15	1	74.2	---	---	0	---	---	---	---
16	2	75.2	9.5	68.5–81.9	1	90.0	---	---	0.4234
17	0	---	---	---	0	---	---	---	---
18	1	66.4	---	---	0	---	---	---	---

[1] Total length in centimeters; $\bar{X}$ = mean, SD = standard deviation, and range = minimum and maximum lengths.

[2] Difference is probability that size at age is same between T1 and T2. Asterisk (*) = significant difference (alpha = 0.05, Duncan's multiple range tests).

[3] Dash (–) indicates no samples or data.

Table 2. Mean back-calculated size by age of red grouper, *Epinephelus morio*, from the eastern Gulf of Mexico in 1979-81 (T1) and 1991-92 (T2).

	T1				T2				T1/T2
		Back-calculated length[1]				Back-calculated length[1]			
Age (yrs)	No. of fish	$\bar{X}$	SD	Range	No. of fish	$\bar{X}$	SD	Range	Difference[2]
2	9	30.2	5.9	25.1–44.0	0	--[3]	---	---	---
3	24	39.5	7.9	29.9–53.5	5	45.2	10.5	33.3–61.3	0.1778
4	22	47.7	8.8	34.3–63.2	26	50.7	5.4	41.1–61.0	0.1544
5	61	50.0	7.4	38.0–67.7	77	56.4	7.3	46.6–87.1	0.0001*
6	33	54.6	9.0	36.8–54.6	71	60.3	7.7	45.7–72.6	0.0012*
7	24	59.5	8.4	39.9–69.7	52	68.0	6.3	50.1–82.4	0.0001*
8	19	61.9	9.5	39.5–77.3	30	71.2	6.6	56.3–83.9	0.0002*
9	6	62.2	9.8	51.6–73.7	13	74.2	6.9	58.9–89.1	0.0069*
10	9	74.4	4.8	66.1–81.0	16	75.3	8.0	51.8–86.2	0.7586
11	8	71.0	5.8	64.6–80.5	3	81.3	6.2	76.0–88.0	0.0301*
12	10	72.5	3.8	66.8–78.0	4	75.3	5.2	70.2–80.9	0.2759
13	6	68.1	7.1	57.8–77.2	0	---	---	---	---
14	1	84.0	---	---	0	---	---	---	---
15	1	73.3	---	---	0	---	---	---	---
16	2	70.1	3.4	67.7–72.5	1	88.1	---	---	0.1461
17	0	---	---	---	0	---	---	---	---
18	1	64.1	---	---	0	---	---	---	---

[1] Total length in centimeters; $\bar{X}$ = mean, SD = standard deviation, and range = minimum and maximum lengths.

[2] Difference is probability that size at age is same between T1 and T2. Asterisk (*) = significant difference (alpha = 0.05, Duncan's multiple range tests).

[3] Dash (–) indicates no samples or data.

Table 3. Mean age at capture by length interval of red grouper *Epinephelus morio*, from the eastern Gulf of Mexico in 1979-81 (T1) and 1991-92 (T2).

	T1				T2			
Length Interval[1/]	No. of fish	$\bar{X}$	SD	Range	No. of fish	$\bar{X}$	SD	Range
30-39	21	2.8	0.7	2-4	1	3.0	-	-
40-49	45	4.9	1.2	2-8	5	4.4	1.5	3-6
50-59	69	5.3	1.5	2-9	91	5.3	1.0	3-10
60-69	61	7.4	3.0	3-18	82	5.8	1.1	3-9
70-79	34	10.0	2.4	6-15	92	7.5	1.6	5-10
80-89	6	11.8	2.6	10-16	24	8.8	1.7	5-12
90-99	0	-	-	-	2	10.7	5.5	5-16

[1/] Total length in centimeters.
[2/] $\bar{X}$ = mean, SD = standard deviation, and range = minimum and maxmum ages.

(Table 2)

$$L_t = 92.6\ (1\text{-}e^{-0.1588\ (t\ +\ 0.9323)})$$

95% C.I.: $L\infty \pm 7.5$, $K \pm 0.0426$, $t_o \pm 0.8364$

T1 and T 2 - back-calculated length at age, collections combined

$$L_t = 79.9\ (1\text{-}e^{-0.2267\ (t\ +\ 0.0566)})$$

95% C.I.: $L\infty \pm 2.3$, $K \pm 0.0252$, $t_o \pm 0.3049$

where L = total length (cm), t = years, C.I. = confidence interval, $L\infty$ = mean maximum attainable length (cm), K = growth coefficient and, t_o = hypothetical age (yrs) which fish would have zero length.

DISCUSSION

The age-size structures of red grouper in the eastern Gulf of Mexico, as indicated by our results, have changed over the 10 years separating the two collections (1979-1981 and 1991-1992) and indicate that fish are larger at age in 1991-1992. Increased red grouper size at age in the eastern Gulf of Mexico in recent years has also been indicated by Goodyear and Schirripa (1991). Comparison of lengths at age developed from von Bertalanffy growth equations (Tables 4 and 5) indicated that lengths at age in our 1979-81 collection was smaller than in our 1991-1992 collection but was similar to Moe's (1969) lengths at age. Fish in our 1991-92 collection, Stiles and

Table 4. Von Bertalanffy growth paramemters of red grouper, *Epinephelus morio*.

		Von Bertalanffy growth parameters[1/]			
Area	Reference	$L\infty$	K	t_o	Study period
FLorida (Central west coast)	Moe (1969)	672 SL mm	0.179	-0.449	1963-1967
North Carolina to Key West, FL	Stiles and Burton (MS)	938 TL mm	0.153	-0.099	1972-1989
Key West, FL to Louisiana	This report	78.9 TL cm	0.1778	0.8259	1979-1981
Key West, FL to Louisiana	This report	92.6 TL cm	0.1588	-0.9323	1991-1992
Key West, FL to Louisiana	This report	79.9 TL cm	0.2267	-0.0566	1979-1992

[1/] L = Mean maximum attainable growth; TL = total length, SL = standard length.
K = Growth coefficient.
t_o = Hypothetical age (in years) at which fish would have zero length.

Table 5. Length at age of red grouper, *Epinephelus morio,* developed from von Bertalanffy growth equations.

Age in years	Total length at age in centimeters				
	A	B	C	D	E[1/]
1	14.5	19.0	21.9	24.5	17.0
2	25.8	28.9	31.2	34.5	29.8
3	34.4	37.1	38.9	43.0	39.9
4	43.7	44.0	45.4	50.3	48.0
5	50.8	49.8	50.9	56.3	54.5
6	56.9	54.6	55.5	61.8	59.7
7	62.1	58.6	59.3	66.3	63.8
8	66.6	62.0	62.5	70.2	67.0
9	70.5	64.8	65.1	73.5	69.5
10	73.8	67.1	67.4	76.3	71.7
11	76.6	69.1	69.3	78.7	73.4
12	79.1	70.8	70.8	80.7	74.7
13	81.2	72.1	72.1	82.5	75.8
14	83.0	73.3	73.2	84.0	76.6
15	84.5	74.2	74.2	85.2	77.3
16	85.8	75.0	74.9	86.3	77.8
17	86.9	75.7	75.6	87.2	78.2
18	87.9	76.3	76.1	88.0	78.6
19	88.8	76.7	76.6	88.7	78.8
20	89.5	77.1	77.0	89.3	79.1

[1/] Sources of von Bertalanffy growth equations.
A = Stiles and Burton (MS), B = Moe 1969 standard lengths converted to total lengths, C = this report 1979-1981 collection, D = this report 1991-1992 collection, E = this report 1979-1992.

Burton's (MS) collection, as well as Shipp's collection (in Goodyear and Schirripa, 1991) were all larger than those in Moe's (1969) collection.

Comparisons between different growth studies should be viewed with caution as differences in size-age ranges, sampling procedures, and data processing may influence the resultant equations. Additionally, management regulations, such as Florida's 1985 minimum size regulation (18 inches TL) which was increased to 20 inches in 1990, may also change the size-age composition in the landings. The changes in the size-age structure of red grouper in the eastern Gulf of Mexico may reflect the species response to either environmental changes or the level of exploitation, as discussed by Johnson et al. (1993) for the gag. Changes in the red grouper's environment have not been documented. Goodyear and Schirripa (1991) presented information on red grouper fishery exploitation. They noted a slow decline in commercial landings from 1962 to late 1970's, after which the landings increased sharply to a maximum of about 5.7 million kg. This increase has been associated with the introduction of new gear technology (power assisted reels and traps) into the fishery. We consider the cause of the changes in red grouper age-size structure in the eastern Gulf of Mexico to be unknown and needs further investigation.

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